

Summary of discussions with colleagues at peer institutions

Institutions and people who contributed:

No.	institution	contact person
1	University of Alberta (UA)	Mauricio Sacchi
2	University of Calgary (UC)	no interview – just news items
3	University of Toronto (UT)	Paul Kushner
4	McGill (MU)	Eric Galbraith
5	Memorial University of Newfoundland (MUN)	Colin Farquharson
6	Stanford University (SU)	Dustin Schroeder
7	Colorado School of Mines (CSM)	Matthew Siegfried
8	Georgia Institute of Technology (GT)	Alex Robel

These colleagues of Christian's responded to his 5 questions in winter 2021. We might want to ask same questions of folks with other perspectives, eg. Catherine (planets focus), Eldad (mathematical focus), Doug (applied geoph; ask for suggestions), Stephanie (ocgy), Susan (ocgy), new fac: Rachel, Anais, Mitch,

The 5 questions posed to peer-institution colleagues.

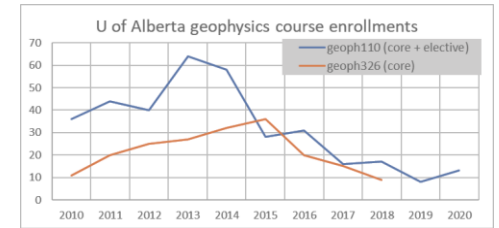
- 1) Your annual program enrollment in recognizable "quantitative earth science" programs. This could be just your earth science offering - here at UBC we have atsci, physical oceanography, geophysics, and geological engineering. Also, what are the enrollment trends (i.e. a time series for 5-10 years works great). In Canada, the feedback I have thus far is that geophysics programs are screwed across the country.
- 2) Do you have numbers for course enrollment in core courses related to geophysics or quantitative earth science in these programs? What trends, e.g. a time series for a couple of sample core courses.
- 3) If the answer to 2) is significantly greater than the answer to 1), why? Do other (non-program) students take these courses and if so, do you know why?
- 4) To what extent are link-ups with non-Earth Science departments key to accessing the desired student demographic, and filling courses?
- 5) Have there been any recent structural changes to your quantitative Earth science programs, and if so, are there discernable impacts they have had on enrollment?

Notes from feedback

1. University of Alberta (UA)

- 1) Annual enrollment in QES program(s) **and** trends

- a) See course geoph326 below
- 2) Enrollment in core QES courses **and** trends
- Intro geophysics (core + elective) 2010 – 2020 →
 - Intro to seismic imaging (core) 2010 – 2020 →
 - Most 4xx are cross listed with 5xx.** Eg geop426 (Time Series) had 3 UG, 6 Grads.
- 3) If (b) > (a) what other students take these courses?
- a) “enrollment in Geophysics (the Chair of Earth Sciences tell me the same for Geology) follows the price of oil lagged by about 2-3 years”
- 4) What links with non Earth Science departments?
- Missing: courses to attract people in ALES (agriculture, life & environmental sciences).
 - Geoph students take much of the physics program, except quantum, optics, & statistical mechanics.
- 5) Recent structural changes to QES programs?
- Structural changes coming to make it easier for **4th yr physics students** to jump into geoph.
 - Challenge: geoph follows APEGA requirements.
 - Part of overall BSc renewal, including making physics more flexible to allow minors.
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.
- “Many of our students are from Alberta and they had a connection to someone with a good job in the oil and gas sector. These jobs are difficult to find nowadays and this is {FJ – or contributes to} why geophysics is not as attractive as it used to be.”
 - 2nd yr computing is basically numerical methods in **Python**. Their 1st yr physics has replaced spreadsheets with Python and geoph. Students take them.
 - Even with strong computing component in geoph, can geoph grads compete with compsci grads?



2. University of Calgary

No faculty member was interviewed, but several CBC news items report on **reduced enrollments** in the BSc. concentration in petroleum geology offered by the department of geoscience ([Oct 6, 2020](#)) and **closure** of their bachelor's program in oil and gas engineering ([July 7, 2021](#)).

This does not relate directly to evolving quantitative earth sciences at UBC since we do not compete with UC in this discipline. In other words, UBC does not have a petroleum industry focus for undergraduate geoscience programs. However, it does highlight the evolving nature of the energy sector, its changing needs for expertise, and by implication, the importance of keeping long term needs of society in mind as we revitalize earth science programs emphasizing quantitative physical, chemical, mathematical and computing disciplines.

3. University of Toronto (UT) (Paul Kushner)

From short notes, presumably from a conversation

- Annual enrollment in QES program(s) **and** trends
 - ~20/yr in geoph specialty of Physics – roughly stable. This is 10% of physics students.
 - “exodus of geophysicists from physics into Earth Sciences”
- Enrollment in core QES courses **and** trends
- If (b) > (a) what other students take these courses?

- 4) What links with non Earth Science departments?
 - a) UofT: geoph is part of physics,
 - b) Earth Systems Science is part of Earth Sciences
 - c) Joint appointments in both exist
 - d) Ocgyl & atsci courses are available as electives to physics students.
 - e) Courses considered “joint physics / earth science” are JPE courses.
- 5) Recent structural changes to QES programs?
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.

4. McGill (MU) (Eric Galbraith)

- 1) Annual enrollment in QES program(s) **and** trends
 - a) No QES program – mainly “geological”.
 - b) Earth System Science has had 3-6 students / yr for 5-10 yrs.
 - c) “numbers are way down in EPS and ATOC.”
- 2) Enrollment in core QES courses **and** trends
 - a) 3-6 students / yr for 5-10 yrs.
- 3) If (b) > (a) what other students take these courses?
- 4) What links with non Earth Science departments?
 - a) None really, except through ESS → ATOC (even more disastrous undergrad numbers) and Geography (which won't want to lose students to other prgms).
 - b) “We do teach a lot of students in the McGill School of the Environment - this has been doing very well in recent years, probably in part because the math requirements are low.” (FJ comment: low math maybe a contributor, but not a cause. These subject areas are currently in higher demand (see Eric's “metaphysical” comment below ...)
- 5) Recent structural changes to QES programs?
 - a) “No, but we should! Happy to share our experience as it unfolds - no secrets on my part”
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.
 - a) Maybe metaphysical turn away from the real world, to a virtual one? Yet envr / sustain prgms seem to be growing, so maybe turn towards bio and away from physical?
 - b) “students who care about 'the environment' would rather avoid math {FJ: or their programs don't require math, but students want to take the programs.}, while most of the students who like math realize that their skills are valuable in the information economy and are headed in that direction.”

5. Memorial University of Newfoundland (MUN)

- 1) Annual enrollment in QES program(s) **and** trends
 - a) “Typical output of the geophysics stream BSc's 8-10 since I've been here, with the worrying exception of the last couple of years!”
 - b) ~20 grads / yr in Earth Science overall
- 2) Enrollment in core QES courses **and** trends
 - a) Small but steady 2005 through ~2018, then significant decline in all ES programmes

- b) 3rd yr app. geoph courses have been down at ~6 in the last two years. Before then it was ~12, and before that ~20.
 - c) undergrad geophysics courses:
 - i) 2 applied geophysics courses
 - ii) mathematical methods for geophysics 3rd year
 - iii) three 4th-yr courses: digital signal processing, seismics, everything-but-seismics, + field school. Geoph students only; ~5 this yr and last few, up to ~10
 - d) Geop stream students often get minor in math by adding 2-3 more courses.
- 3) If (b) > (a) what other students take these courses?
 - a) 3rd yr appl geophysics courses (2 of them) taken by ~5-10 geology students (down from ~20). (One app geop course rqr'd for professional registration in NL.)
 - 4) What links with non Earth Science departments?
 - a) Joint geoph-phys, but only 1 stu every couple years as scheduling of courses makes it impossible to complete in 4 yrs.
 - b) Physics dep't is in fact "physics and ocgy"; no concrete knowledge, but some modeling & field obs.
 - c) Math dep't is mainly theoretical, not applied.
 - 5) Recent structural changes to QES programs?
 - a) None, but "problems" are described. Eg, less math than optimal; programming (python) that is underwhelming; lots of geology since it's a BSc in Earth Sciences;
 - 6) Other comments related to enrollments, trends, courses, partnerships, programs.
 - a) "We're having issues as well; would be useful for us all to learn from each other."
 - b) Geology courses also in decline; we're not sure why. We think not purely a funk in the oil industry.
 - c) Most students are doing geophysics or geology to get a job: oil or minerals.
 - d) "Our students are pretty well liked in jobs they take upon graduation because fieldwork is almost always part of such a job. Therefore, little room for more math for geophysics. Pros and cons."
 - e) "Students with our BSc may not be suited for a grad degrees with the likes of Oldenburg / Haber, but they are very well suited for other things, including jobs, and that's perhaps a lot more important!"

6. Stanford University (SU) (Dustin Schroeder)

- 1) Annual enrollment in QES program(s) **and** trends
 - a) In geoph major: 2016-2020: 2, 2, 0, 5, 8
- 2) Enrollment in core QES courses **and** trends
 - a) Intro to geophysics: 2016-**2020**: 7, 30, 14, **40**
- 3) If (b) > (a) what other students take these courses?
 - a) "we meet the physics requirements for the earth systems major and are a science track in the physics major and a science elective for others".
- 4) What links with non Earth Science departments?
 - a) "I think it's utterly key."
- 5) Recent structural changes to QES programs? "We have been working to revitalize our geophysics major", and "yes, a small, flexible, research-based quantitative major that's growing in popularity. Definitely feels like we're on a growth track." Details:
 - a) They started from "zero students"

- b) Goals: **take advantage of what we are** and have explicit pipelines for 2 types of students:
 - i) environmental studies students who are scared of math but may discover they like it after all,
 - ii) physics/engineering majors who discover there is quantitative earth science.
 - c) Social events, e.g. at a faculty member's home twice a year for majors + faculty; builds community and commitment among both faculty and students.
 - d) **Each ugrad has several mentors:**
 - i) Director of ugrad studies
 - ii) A faculty mentor based on match-making process
 - iii) Grad student also based on a matchmaking process
 - iv) Research advisor for thesis (maybe same as (2))
 - v) Ugrad peer advisors: one "charismatic" senior gets a part-time job to hold office hours, homework events, social events.
 - e) Cut required core courses down focusing on the core strengths of our department:
 - i) Measurements, Instruments, Fields and Waves (which I teach),
 - ii) Mathematics, Computation, Mechanics and Dynamics (which Eric Teaches), and
 - iii) Laboratory Studies (which Tiziana teaches).
 - iv) Intro seminar course; a "parade" of short faculty talks, a recitation/tutorial involving short readings and one problem created by each professor (breadth of the department) [FJ: could be EOSC 212]
 - v) a thesis-writing senior capstone.
 - vi) This makes it possible for people to "discover" us in their 3rd or 4th year (from another STEM major) and switch to geophysics (or add it as a second major)
 - vii) All other courses are "geophysical electives" – a "caltech style" experience where undergrads take courses with mostly grad students or from across campus (with approval).
 - f) Focus on teaching well. (They likely benefit from Stanford's Weiman group.)
 - i) Watch reviews and keep faculty appraised & supported.
 - ii) Polish courses, package resources and strategies, and work with co-teachers to ensure sustainability.
 - iii) Non-core courses are electives taken by both grads and undergrads – "Caltech style".
 - g) For recruiting and marketing:
 - i) meet with leaders of other programs to discuss our courses and to get them listed on websites and in bulletins and as options for other programs.
 - ii) Meet with academic advisors to explain our major
 - iii) attend as many "first year" major shopping events as possible
 - iv) volunteer as a "pre-major advisor" (and pester colleagues to do so too).
 - v) Lobbied to offer guest lectures in courses in other majors/schools targeting incoming students (I do one in physics, one in engineering, and one in data science) to get students interested.
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.

7. Colorado School of Mines (CSM) (Matthew Siegfried)

- 1) Annual enrollment in QES program(s) **and** trends
 - a) "Enrolment issues of our own"

- 2) Enrollment in core QES courses **and** trends
 - a) Matt refers to Brandon Dugan for numbers.
- 3) If (b) > (a) what other students take these courses?
- 4) What links with non Earth Science departments?
 - a) close working relationship with our Computer Science department
 - b) Comp. Sci. 250 (Python Computing: Building a Sensor System) is taught every other semester **by geophysics faculty**.
 - c) We are trying to deepen these cross-department collaborations.
- 5) Recent structural changes to QES programs?
 - a) Significant recent upgrade to curriculum.
 - b) [Geophysics](#) page with faculty, major, minor, courses.
 - c) Program [flowchart PDF](#) (this is nice!)
 - d) **more classes with compute** (~2 yrs of python for undergraduates)
 - e) Re. new curriculum: *"You don't see the gaps until you grind the crank a few times"*. Therefore, assessing impacts of change 3-5 yrs later is critical – **eg. a special retreat**.
 - f) Need to make sure the **learning goals are aligned across the whole curriculum**.
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.
 - a) "branching out" in terms of hiring and application of geophysics
 - b) Geop faculty don't teach any required 1st yr courses. **1st yr students don't "see" geoph.**
 - c) Geop faculty hoping to access one section of the campus Earth Sci. 101. But – political because of the benefits of "monopolizing the eyeballs" of 1st yr students.
 - d) Transition into geoph after sophomore is hard owing to requirements.
 - e) Struggling to change the **out-of-classroom culture about careers**. Eg: alumni at Maxar/DigitalGlobe, DoD-funded machine learning start ups, non-seismic grad school positions, etc.
 - f) Initiatives to engage with **alumni** throughout curriculum, eg "alum panels" in courses.
 - g) **Nested mentoring** – senior (& grad) students helping younger ones.
 - h) Renewing grad curriculum "soon".
- 7) QUESTIONS:
 - a) Were there comments from Brandon Dugan (assoc dep't head) re. curriculum renewal?

8. Georgia Institute of Technology (GT) (Alex Robel)

- 1) Annual enrollment in QES program(s) **and** trends
 - a) ~15 / year.
 - b) Trying to align "branding" to capture more students from the engineering
- 2) Enrollment in core QES courses **and** trends
 - a) In Earth and Atmospheric Sciences: 2010-2014-2020: ~60-30-60.
 - b) ****Dedicated version of 1st yr course for students intending to major in EAS.** (FJ comment: This may not to attract students but does offer more focused intro. to ~30 EAS students.)

- c) A few popular electives on climate and energy have 30-60 students (taught by in-demand faculty like Kim Cobb).
- 3) If (b) > (a) what other students take these courses?
 - a) Intro courses have ~1500-2000
 - b) New upper level elective on “sea level and coastal engineering” attracted 25 engineering students.
- 4) What links with non Earth Science departments?
 - a) At GT, 20k ugrads, 80% engineering / compsci.
 - b) Noted that GT doesn’t feed oil/gas/mining
- 5) Recent structural changes to QES programs?
 - a) currently in the process of renaming the existing quant-heavy major as “**computational EAS**”
 - b) also introducing a second less quant-heavy major
 - c) **Course list** for this B.Sc. Major was given – see Alex’s email
 - d) Intro to Quant Methods for Earth Science course (in yr 2); an intro to MATLAB (and **now python**) and stats.
 - e) **Earth system modeling** (taken some time after diff eq): intro to numerical methods, lots of coding & techniques useful to earth scientists: box modeling, simple inversions, 1D PDEs, etc. (upgrade aims to be more “practical”).
 - f) “Future grad students will take more advanced numerical methods later anyway.”
- 6) Other comments related to enrollments, trends, courses, partnerships, programs.
 - a) “rebound” in numbers attributed to “>introducing majors section for our introductory classes, >improving advising and professional development, and >building a greater sense of community”.
 - b) Anticipates continued migration away from QES as other quantitative (eg. engineering) programs are more practical and obviously attractive.

Good ideas, and thoughts arising from these communications.

- 1) Illustrate and emphasize how quantitative expertise learned in an Earth science context will be in demand in the energy and environmental sectors. Meanwhile, demand in non-petroleum resource sectors will remain small but constant, while land-use, natural hazards and climate-related occupations will likely grow (needs ref. – AGI?).
- 2) Curriculum design: **learning goals** must be clear and aligned across the whole curriculum.
- 3) **Three to five yrs later**: impact assessment and curriculum review & assessment is critical.
- 4) Visibility at **first year** is critical.
- 5) ****Plan an out-of-classroom component to curriculum renewal**, eg. educating campus career center, coop office, student support groups at faculty level, student clubs, etc. eg. “alumni panels”.
- 6) Nested **mentoring** – students helping students, including grads. Maybe leverage worklearn students to spread words about what work they did in EOAS.
- 7) **Stanford’s** (Dusty’s) efforts are inspiring: see 7 items under “recent structural changes” for Stanford.
- 8) Maybe we should have most 4xx cross listed with 5xx. We sort of do already, but maybe others? (Although grads are actually allowed to take limited number of 4xx courses.)

Summary:

Questions posed: Q1. QES Enrolment & trends. Q2. enrolment & trends in QES core courses; Q3. If (2) > (1) why? Q4. links with non-EOAS students & dep'ts? Q5. recent structural changes to QES?

	1. Alberta	2. Calgary	3. UofT	4. McGill	5. Memorial
	Mauricio Sacchi	none	Paul Kushner	Eric Galbraith	Colin Farquharson
Q1	from 20-30 to ~10	^reductions in O/G prgrms; 2 news items quoted	~20/yr stable BUT geoph do move to Earth Sci.	EarthSys=3-6	8-10 but declining
Q2	3 ug + 6 grad	na	na	3 to 6	down since 2018
Q3	enrollements lag O/G prices by 2-3 yrs	na	na	na	3rd yr app-geoph taken by 5-10 geol students but down from ~20
Q4	none	na	phys can tak ocgy/atasc electives; joint phys/EarthSci	none; ESS -> ATOC, but v. small	
Q5	enable 4th phys to jump into geoph; make taking "minors" easier to do	na	na	none	none; but a few caveats
Neg	APEGA is constraint; visibility of geoph is a prob; Alta O/G context is a limiting reality	na	na	Quantitative students turn to "inform'n economy"	geol is down too;
Pos	2nd yr cpssc is "numerical methods in Python"	not UBC "competition" owing to O/G emphasis	Geop is in Phys. & electives are available to phys students	ENVR (low QES) has done well	geoph students are job-oriented
Notes			- Geop is in Phys.; phys can take ocgy/atasc electives. - joint phys/EarthSci. Courses	Quantitative students turn to "inform'n economy"	- generic courses by yr were outlined - if geoph students are job-oriented then math/phys less important

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	6. Stanford	7. CSMines	8. Georgia Tech	9. MIT	10. Princeton
	Dustin Schroeder	Matthew Siegfried	Alex Robel	na	na
Q1	2 - 8	na	~15/yr	na	na
Q2	40	na	~60 in Earth and atmospheric sciences	na	na
Q3	na	na	large 1st yr courses,	na	na
Q4	"links to other dep'ts are utterly key"	close rel'n with CompSci & aiming for more	GT is 80% eng/compsci, & no resource focus	na	na
Q5	Many^^	yes, changed, see links below	new in 2023: AOS, ENVS, SEP	na	na
Neg	none	1st yr CSM sees no geop	Anticipates continued migration away from QES as other quantitative (eg. engineering) programs are more practical and obviously attractive	na	na
Pos	small research-based QES - unique Stanford context	working on culture, mentoring & alumni.	>showcase majors in intro. courses, >improve advising / professional dev., and >community building	na	Na
Notes	- links with other dep'ts are utterly key - revitalized geoph is on the right track^^ - geophysics program	- geoph prgm - prgm flow (8yrs old) - Alumni recognized as a resource for marketing	- 3 new degrees - has a first year course for EAS students - Earth system modeling course after DEs - attributes growth to: >showcase majors in intro. courses, >improve advising / professional dev., and >community building	- " Fundamental background via dep's subjects & advanced study in a concentration of student's choice " - joint BSc in climate system science & engineering - Minor in EA&PS	- BSc Geosci. - 5 tracks, 2 are QES - Climate Sci Minor